Ocean Observer SAR Requirements and Instrument Characteristics

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***Abstract* — This paper is a brief summary of the synthetic aperture radar (SAR) user requirements, satellite requirements, and instrument requirements for the proposed, but yet unfunded, U.S. Ocean Observer Satellite.**

I. Introduction

During the past two years, operational measurement requirements for the future U.S. operational environmental satellites have been extensively revised. These requirements specify the operational measurements to be made from the National Polar-orbiting Operational Environmental Satellite System (NPOESS) which is planned for the 2008 to 2018 time period. NPOESS meets the operational needs of the U.S. civilian meteorological, environmental, climatic, and space environmental remote sensing programs, and the Global Military Space and Geophysical Environmental remote sensing programs. This system, however, does not meet all the needs of the user community interested in operational oceanography (particularly in coastal regions) and hazard response. Beginning in the fall of 2000, the Integrated Program Office, a joint Dept. of Defense (DoD), Dept. of Commerce (DOC), National Aeronautics and Space Administration (NASA) office, initiated the Ocean Observer Study (OOS). The purpose of this study is to: (1) determine what additional ocean and hazard observations from space are needed in the 2008 to 2023 time period; (2) turn these needs into requirements; (3) examine instrument and satellite options to meet these requirements, and (4) determine the costs for building such an ocean observation satellite. The user requirements study done for the OOS indicates that one of the primary sensors needs to be a synthetic aperture radar (SAR), preferably a multi-frequency, multi-polarization, multi-mode, interferometric instrument. This paper summaries the SAR ocean measurement requirements resulting from the OOS, the SAR characteristics necessary to fulfill the measurement requirements, and some preliminary instrument and satellite requirements. It must be emphasized that this satellite is still in the conceptual phase and is not an approved or funded program.

II. SAR user requirements

As the first step in the Ocean Observer Study, an Ocean Observer User Requirements Document (URD) was compiled. This document was developed by an extensive User Requirements Team consisting of over 150 scientists in many U.S. Government (USG) agencies, academia, and private industry. Each group of parameters, called Environmental Data Requirements - or EDRs (e.g., sea surface winds, sea surface height, sea ice) was specified by a separate team which developed and refined the requirements for that environmental parameter or group of related parameters. A typical EDR consists of a definition, a table of requirements, an explanation, and a justification There are two sets of requirements for each EDR: (1) minimally acceptable requirements (Threshold), and optimum requirements (Objective). See the NPOESS web site for a draft of the URD (http://npoesslib.ipo.noaa.gov/oos.htm).

In the Ocean Observer URD, emphasis was placed on ocean parameters; however, cryospheric (e.g., Sea and Lake Ice Concentration/Age/Motion/Edge Location), hydrologic (e.g., Flood Mapping), land (e.g., Land Surface Deformation), and atmospheric (e.g., Mesoscale Atmospheric Features) parameter requirements were included if the parameter could be generated by the same technology needed to meet the ocean requirements. An emphasis on coastal ocean observations (e.g., coastal winds) emerged as the study progressed. Although the requirements definition process is not entirely complete, the requirements that have been defined have been extensively reviewed. All the ocean requirements generated by DoD and DOC which are defined in the Ocean Observer Study have also been incorporated into the official NPOESS Integrated Operational Requirements Document II (IORD II), although many of these requirements

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are part of the preplanned product improvements (i.e. unfunded) section of that document (the IORD II is available on the NPOESS web site: http://www.ipo.noaa.gov). Many of the ocean parameters in the IORD II and the Ocean Observer URD (e.g., global sea surface temperature, ocean color) will be generated from two instruments planned for the NPOESS satellites: the Visible/IR Imaging Radiometer Suite (VIIRS) and the Conically scanning Microwave Imager/Sounder (CMIS). In addition, the Advanced Scatterometer (ASCAT) to fly on the European METOP satellite operated by EUMETSAT will provide scatterometer winds for NPOESS. Other ocean parameters, however, cannot be provided, at least by the U.S., without the instruments proposed for the Ocean Observer Satellite (i.e., a coastal ocean imager, an advanced altimeter, and a synthetic aperture radar). Of the 56 EDRs listed in the Ocean Observer URD, a SAR instrument is the primary instrument for the derivation of 31 of these. Since this paper is focused on the SAR instrument proposed for the Ocean Observer Satellite, only the SAR-derived parameters are discussed below.

Table 1 summarizes the SAR-derived ocean parameters and suggests the desired characteristics of a SAR instrument designed to measure these parameters (Note that some of the URD EDR's have been combined and some split up in Table 1 to better specify the SAR characteristics required).

III. SAR SATELLITE AND INSTRUMENT CHARACTERISTICS

At the NASA Jet Propulsion Laboratory (JPL), instrument and satellite scientists and engineers analyzed the requirements in the Ocean Observer URD including the summary in Table 1 and proposed a number of SAR instrument and satellite characteristics to satisfy the maximum number of requirements. These initial instrument and satellite designs were followed by a round of discussions between the User Requirements Team and the Instrument and Satellite Teams, culminating in the following general requirements for the SAR instrument and the satellite system to carry it.

A. Ocean Observer SAR Mission Satellite Characteristics:

Mission length – 15 years with 3 satellites, each with a lifetime of 7.5 years. The second satellite should be launched after the first 5 years of the mission so that there can be 2.5 years of formation flying for cross-track interferometry. The final satellite should be launched after 10 years into the mission to allow an additional 2.5 years of cross-track interferometry. During formation flying one satellite should trail the other by about 10 minutes.

Orbit – Polar, sun-synchronous with 1:00 pm ascending equator crossing time with an 8-day exact repeat orbit (designed for interferometry) and an altitude of approximately 800 km. Orbit should exactly repeat within a 100 m tube for C-band repeat-pass interferometry.

Maneuverability – Satellite can be rolled so that the SAR antenna is viewing either left or right of nadir.

Power and recording capability – The SAR can be on and recording for 10 minutes in eclipse and 20 minutes in daylight each orbit.

Acquisition system – Time delay between observation and image/product availability should not be more than 2 hours

Instruments – SAR (as described below), Coastal Ocean Imager (a 100 m resolution, 150 km swath, 64 channel Visible/Infrared Spectrometer), and a passive microwave radiometer (to aid with soil moisture measurements).

B. SAR Instrument Characteristics:

Frequency – Dual frequency (C-band and L-band) SAR, operated simultaneously or independently

Polarization – L-band has quad polarization, C-band has dual polarization

Modes – Multiple (see Tables 2 and 3)

Interferometry – Repeat-pass (for land deformation), cross-track (for topography - during times when two satellites are flying), and Along-Track (for ocean current measurement – C-band only). L-band can make split-spectrum measurements to improve ionospheric corrections

Angle of Incidence – 15 degrees or greater, no coverage hole at the North Pole, higher-resolution modes can be positioned over a wide range of angles of incidence to maximize repeat coverage of selected targets

Noise – Noise equivalent σ_o: –28 dB or better for C-band and –37 dB or better for L-band.

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TABLE I
SAR CHARACTERISTICS FOR OCEAN OBSERVER EDR APPLICATIONS

		FREQ.		POLARIZATION					INTERFEROMETRY		
EDR	EDR TITLE	C	L	VV	HH	Dual	Cross	Quad	ATI	CTI	RPI
	OCEANIC										
1	Coastal Sea Surface Winds & Wind Stress	P		P	S						
2	Wave Characteristics - Significant Wave Height		P		P						
3	Wave Characteristics. - Ocean Wave Direction/Wavelength	S	P		P				A		
4	High Resolution All Weather Imagery										
5	Oil Spill Location	P	A	P	S	A					
6	Vessel Positions	P	S	S	P				A		
7	Bathymetry (Near Shore)	A	P	S	P	A			P		
8	Ocean Currents	P	P	P	S				P*		
9	Surf Conditions	P	S	S	P		A		A		
10	Ocean Mesoscale Features (Fronts/Eddies)	P	P	S	P		A				
	CRYOSPHERIC										
11	Sea Ice Concentration and Edge Location	P	A	P	P		A	A		A	
12	Lake Ice Concentration/Type, Motion, and Edge Location	P		P*	P*		P	A			
13	Sea Ice Type	P	A,S	S	P			A			
14	Sea Ice Motion	P	A		P			A			
15	Ice of Land Origin (Icebergs)	P	S	S	P						
16	River Ice Location/Condition		P								
17	Glacier Volumetric Change	P	S	S	P					P	S
18	Continental Ice Sheet Melt Zone	P	S	S	P						
19	Ice-Sheet Motion	S	P	S	P	S					P
20	Ice-Sheet Grounding Line Position	S	P	S	P						P
	HYDROLOGIC										
21	Flood Mapping	A	P		P	A		A			
22	Snow Water Equivalent Mapping	P	P*					P			
23	Soil Moisture	A	P		P	P					
24	Coastal Wetland Mapping	P			P			A			P
	LAND										
25	Land Surface Topography	S	P					P		P	
26	Land Surface Deformation	A	P		P						P*
27	Land Surface Freeze/Thaw State		P		P						
28	Vegetation Classification/Biomass	A	P					P			
29	Coastal Change	P	P					A			P
	ATMOSPHERIC										
30	Atmospheric Features	P	S	P							

KEY: P=Primary, S=Secondary, P*=Required, A= Additional Capability, Dual = VV & VH or HH & HV, Quad = VV, VH, HH, and HV, Cross = HV or VH, ATI = Along-Track Interferometry, CTI = Cross-Track Interferometry, RPI = Repeat-Pass Interferometry

TABLE 2
L-BAND SAR MODES OF OPERATION

Mode of Operation	Fine Mode	Quad Polarization	Dual Polarization	Standard Mode	Split Spectrum	Scan SAR Narrow a	Scan SAR Narrow b	Scan SAR Wide
Resolution (m)	**10**	**25**	**25**	**25**	**25**	**50**	**50**	**100**
Ground Swath (km)	**30**	**50**	**100**	**150**	**150**	**350**	**350**	**600**
Number of Looks	**3**	**2**	**4**	**4**	**4**	**4**	**4**	**8**
Polarization	**HH**	**HH, HV, VV, VH**	**HH & HV, or VV & VH or HH & VV**	**HH or VV**	**HH or VV**	**HH & VV**	**HH or VV**	**HH or VV**

TABLE 3
C-BAND SAR MODES OF OPERATION

Mode of Operation	Fine Mode	Dual Polarization	Standard Mode	ScanSAR Narrow a	ScanSAR Narrow b	ScanSAR Wide a	ScanSAR Wide b
Resolution (m)	**a) 5 b) 10**	**25**	**25**	**50**	**50**	**100**	**100**
Ground Swath (km)	**a) 25 b) 30**	**100**	**150**	**350**	**350**	**600**	**600**
Number of Looks	**a) 2 b) 3**	**4**	**4**	**4-7**	**4-7**	**10-20**	**10-20**
Polarization	**HH or VV**	**HH & HV or VV & VH or VV & HH**	**HH or VV**	**HH & VV**	**HH or VV**	**HH & VV**	**HH or VV**

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